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Production and Characterization of Biodegradable Polymer From Jicama Starch (*Pachyrizus Erosus*) And It's Biodegration In Soil

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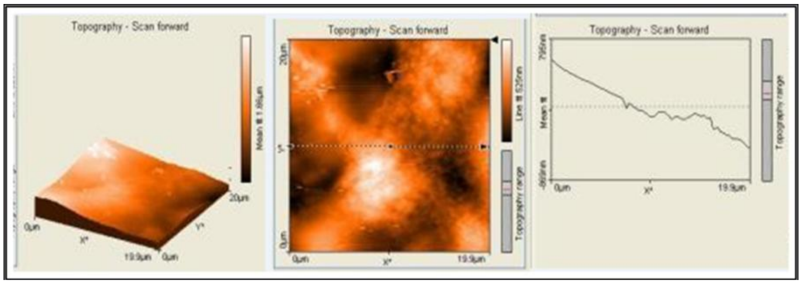
ABSTRACT

Jicama starch is a polymerized carbohydrate that forms biodegradable polymer with the addition of glycerol at temperature of 80°C. Biodegradable polymers formed were dried and tested with Tensile Strength test, thermal properties test, Fourier Transform Infra Red (FTIR), soil biodegradability test, Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). The results obtained showed a flexible and elastic tensile strength properties and thermal properties of melting point at 105°C temperature. FTIR showed a specific peak at 3300 cm^{-1}wave and the O-H peak of hydroxyl reinforced by a range of C-O at wave number 1300 to 1000 cm^{-1}. SEM showed degradation towards biodegradable polymer.

Graphical Abstract:



AFM Biodegradable Polymer from Jicama Starch

Keywords: Biodegradable, Polymer, Carbohydrate.

INTRODUCTION

Plastic is an important polymer in daily life. The needs for plastic tend to increase because of the benefits of its practical characteristic. Plastics are widely used as storage containers and food wrappers. In addition to providing practical benefits in daily life, plastics have negative impact towards environment. The difficult-to-decompose nature of plastics results on environmental pollution. Harmful chemical contents of plastics such as *polyvinyl chloride* (PVC) particularly used as food wrappers, will cause some health risk to humans. PVC contained in food wrappers will be migrated to the food. Thus, alternatives to change this kind of plastic role need to be investigated and those are biodegradable polymers that do not contain harmful chemical compound, especially for food packaging.

Carbohydrate polymer is one of alternative researches to replace the role of plastic that is not biodegradable [1]. Biodegradable polymer becomes very interesting object for advance development. Biodegradable polymer has similar structural and functional characteristics to plastic in general. However, it is derived wholly or partially from biological material such as rice starch [2,3]. Biopolymers often have low characteristic if compared to the properties of commodity polymers. Modification becomes a way to improve the properties and achieves the combination of properties required for a particular application. One technique used is to create a mix that allows a big improvement in the impact resistance of the brittle polymer [4].

Starch is widely available and it is an energy reserve found in plants that contains amylase and amylopectin. These two can be used as material for the manufacture of biodegradable polymers with pemplastis glycerol or sorbitol. Starch-based thermoplastic material (TPS) has a bad characteristic, especially in high humidity and therefore it's mostly mixed with synthetic/biodegradable polymers such as PLA, PHB, or PCL. They have been successfully applied at the industry level for foaming, film blowing, injection molding, blow molding and extrusion applications [5]. The study is developed with a base made from the sugar palm starch. Starch material added with glycerol of 15-40 w / w% has established bioplastics [6]. Starch contained in palm sugar contains polymerized carbohydrate and has biodegradable characteristic [7]. Tapioca starch with the addition of metilenfenil diisocyanate succeeds in increasing the appeal of bioplastics. While the addition of acetyl butyl citrate increases ductility toughness of tapioca that makes it more plastis [1].Biodegradable film also develops from isolation of banana flour and starch. The results show that banana flour is mechanically non-durable but it is more flexible compared to banana starch film [8]. Biodegradable polymer is also developed by molding injection method, with material base that contains protein and addition of glycerol as plasticizer. Bioplastic is created with transparent characteristic [9-11]. The effect of glycerol (35%, 40% and 45%) and water activity (0,34 and 0,48) physically, mechanically and morphologically from albumin base bioplastics is compressed and investigated. This study shows that compressed albumin-based bioplastic with desirable characteristic can be obtained by adjusting the water activity and glycerol contents for whole synthetic process [12]. This issue is very interesting for the development in chemical material sector that is why it's important to conduct the study about making and characterizing biodegradable polymer from Jicama starch. Besides, Jicama is one of food materials that contains carbohydrate, and scientific name of Jicama is *Pachyrizus erosus***.**

MATERIALS AND METHODS

Method used in this study was true experimental research done in laboratory. Whole process of this research was made reference to previous similar research. Biodegradable polymer from cassava starch was synthesized with the addition of polystyrene and potassium persulfate as initiator and water as the media. Bioplastic formed had characteristic without gelatin starch [13]. Thermoplastic starch was also created from palm material with the addition of glycerol. Thermoplastic characteristic with the increasing of glycerol addition was decreasing the plasticizer absorption towards water [6]. Materials used in this research were Jicama starch obtained from some farmers in Padang city, distillate water, and plasticizer (glycerol/glycerin). Tools used in this research were hot plate, glass, autoclave, mold and tools for Tensile strength, FTIR, DSC, AFM, SEM and tools for degradation test.

The first step to create Jicama starch as basis material for biodegradable polymer synthesize was peeling and washing the Jicama, then the material was grated. Grated Jicama was then strained and the deposition was collected and dried. Next Jicama starch was weighed with certain number (b/v) in gram. The starch was dissolved with distillate water and stirred, after that it was heated in hot plate and added with glycerol. The solution was chilled and poured into mold and dried in the oven.

RESULTS AND DISCUSSION

Jicama starch that turned into biodegradable polymer after the addition of glycerol was chilled and dried with oven. Biodegradable polymer created underwent some tests. The tests were done to know the success characteristic of bioplastic formed.

Tensile Strength Test: The result of appeal test done always draws one kind of material (in this matter bioplastic from Jicama starch) until it breaks. This will show a complete pulling profile in a curve form that can be seen in Figure1. This curve shows the relationship between pulling force with length alteration. Based on Hooke's Law, the stress and strain ratio is constant. The relationship between the load and force given is directly proportional with the alteration of material length. This is called as linear zone. Stress is obtained from dividing the load by the cross-sectional area, while strain is length addition divided by initial length of the material [14].

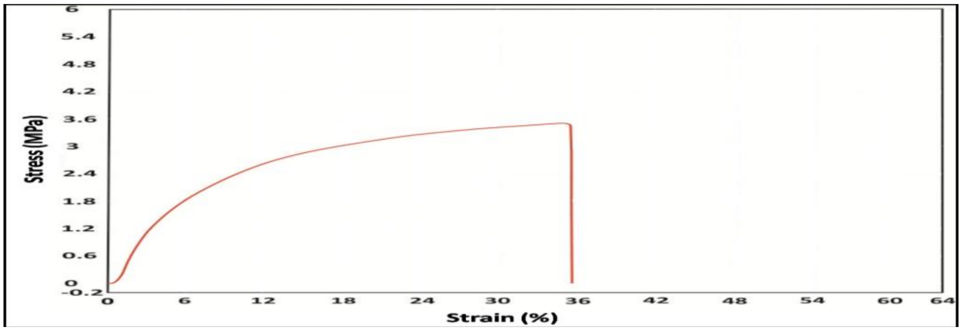


Figure 1. Curve graphic of biodegradable polymer tractive-power from Jicama starch

Results of Jicama starch graph show the yield point at + 1.8% strain with tension or stress of +0.75 MPa while the breaking point on Jicama starch biodegradable polymer occurs at + 31.5% and +3.65 MPa. These results show that biodegradable polymer of Jicama starch is flexible and elastic.

Thermal Characteristic Test: DSC (Different Scanning Calorimeter) results show glass transition temperature (Tg) and melting point temperature (Tm). Glass transition temperature is the temperature where plastic changes its condition and characteristic from rigid, brittle and glass-solid, into flexible, soft, and elastic. Melting point indicates the temperature at which the plastic changes from solid into a liquid form. Melting point is called as first-order transition, while glass transition temperature is second-order transition. Figure 2 shows Tg onset at ± 105°C and Tg midpoint at ± 272°C. This value is higher than palm sugar starch that is 242,14°C. The low value is caused by low concentration of glycerol [6].

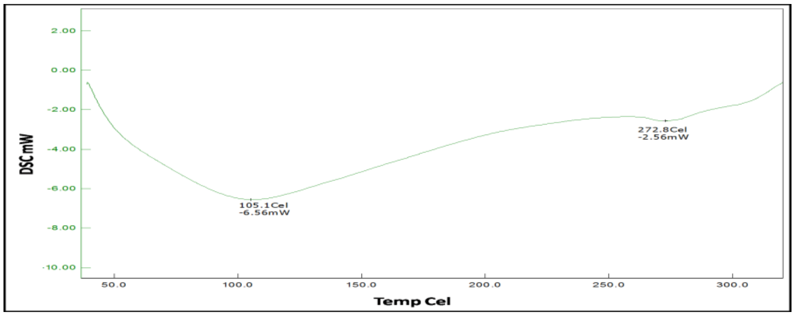


Figure 2. DSC Biodegradable polymer from Jicama starch

FTIR Analysis: Infrared Fourier Transform analysis is done to investigate each structural change that has happened [15]. FTIR analysis is done to decide cluster function contained in the starch and compare it to the bioplastic from durian seed starch. Specific peak found in this test is at wave number around 3300 cm^{-1}; it shows the O-H hydroxyl peak powered by C-O stretches at 1300-1000 cm^{-1} wave number (Fig.3) It shows alcohol cluster function that derives from glucose structure of starch, glycerol and CPO.

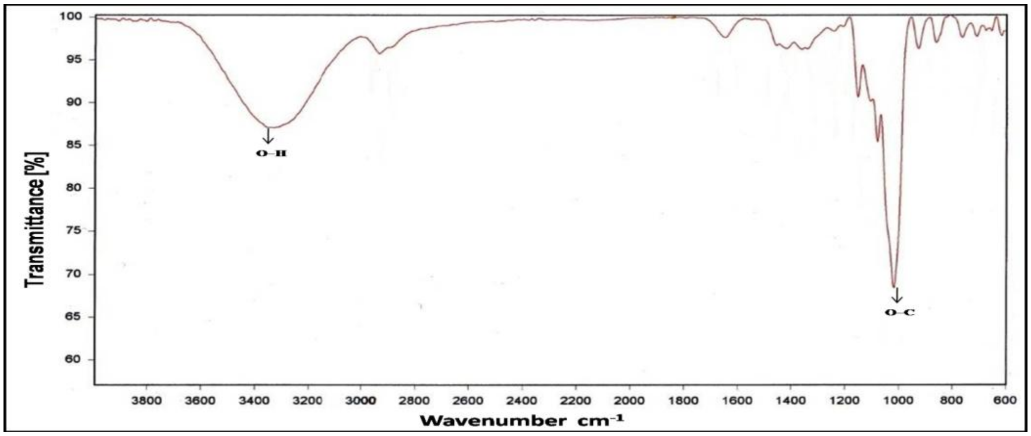


Figure 3. FT-IR Biodegradable Polymer from Jicama Starch

Soil Biodegradability Test: Biodegradability test is a major goal in the manufacture of plastic-based biopolymer. It's used to determine the ability to unravel as the application of environmentally friendly plastic. Biodegradability can be done by the hydrolysis (chemical), bacteria/fungi, light (photo-degradation) and others. In this study, biodegradability test is done by using soil-burial test where the sample is buried in the ground [16].

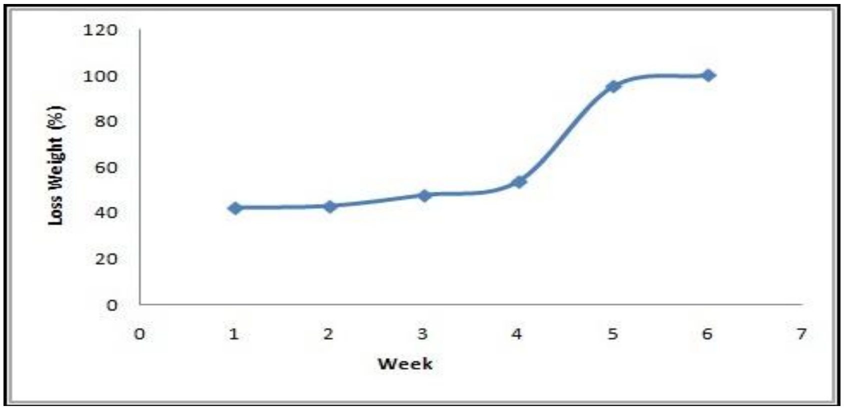


Figure 4. Graph of Biodegradability Test Result of Biodegradable Polymer from Jicama Starch

Simulations are carried out for testing in the laboratory. It is expected when the Jicama starch bioplastics buried in the soil, they can be degraded by soil microbes. Synthetic polymer may trigger the degradation process in the soil. With starch degradation processed by soil microbes, it is expected that the polymer chains will also be disconnected. Microorganisms, in this case the mold, will produce enzymes that are capable of breaking down starch in the plastic into smaller segments with lower molecular weight. This condition causes the polymer material becomes degradable in the environment [17]. Glucose produced by the enzyme from starch hydrolysis will be used by microorganisms as a carbon source [18]. By using microorganisms, it was suspected that starch that has been degraded and cannot be removed by amylase will be consumed all by microbes, so it was expected that 20% starch content in bioplastics will be eroded by the microorganisms (Fig 4).

SEM Test: Test towards degradation of Jicama starch bioplastic is also done by SEM test. The purpose of this test is to observe the changes of bioplastic morphology before and after being degraded by microorganisms. Based on the morphology before degradation processed by microorganism, bioplastic biodegradable polymer characteristic shows no pores on the surface (Fig. 5A and Fig. 5B). While based on the test result obtained, the morphology after degradation process shows that degradation towards Jicama starch bioplastics has been done. This analysis proved that there is the creation of pores after degradation (Fig. 5C). The important feature from the soil burial test is that the biodegradation of the film increases with increasing amounts of starch acetate [16].

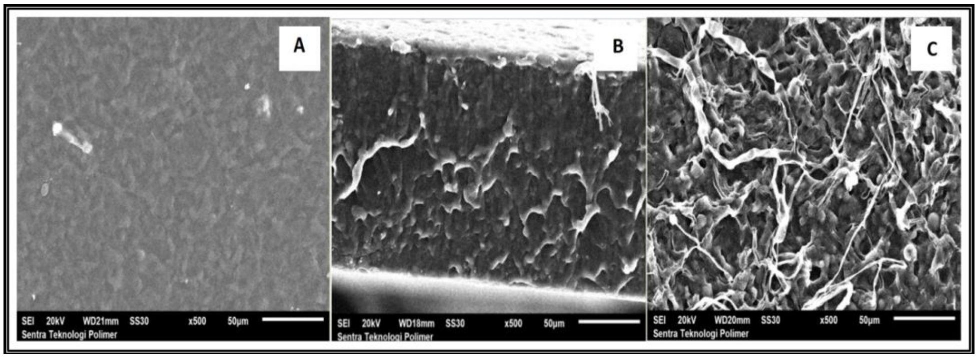


Figure 5. SEM biodegradable polymer is viewed from the surface before the degradation process (A), SEM biodegradable polymers of cross section is viewed from the direction before the degradation process (B) and SEM biodegradable polymers after a degradation in soil (C)

AFM Test: Atomic Force Microscopy (AFM) is a microscopic surface scan that shows three-dimensional topography with tip as detection tool. One of the most important characteristics from the image obtained by AFM is 3D geometry of the object that enables more detailed analysis of sample profile morphology by using the morphometry [19, 20]. Jicama starch bioplastic visualized by AFM scan shows a homogenous surface morphology, surface infrastructure represented by globular formation from the same type. Parameter dimension of globular structure visualized from Jicama starch bioplastic material are: length 9.18 µm, wide 8.76 µm, and height84.46 nm. The space between globular formations reaches 139.1 nm. The analysis of development level using square roughness mean parameter (Rq, deviation of profile point from the diameter) shows that surface of starch-based bioplastic materials has uniform texture with Rq value of 98 nm.

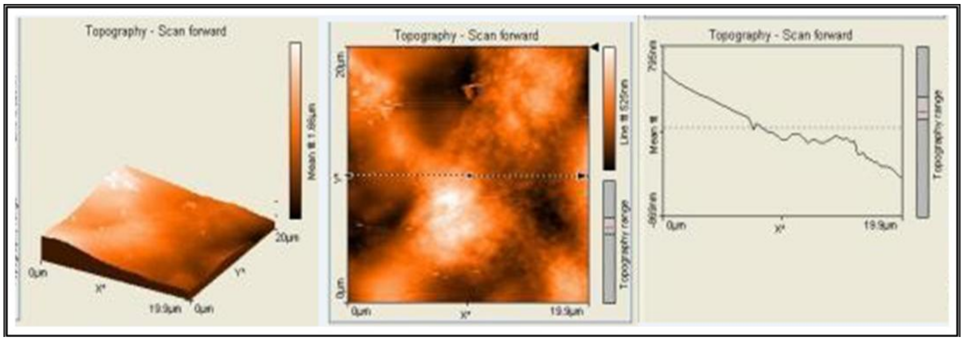


Figure 6. AFM Biodegradable Polymer from Jicama Starch

CONCLUSIONS

Jicama starch can be made into bioplastics with the addition of glycerol w/w%. The tensile strength properties resulted from the biodegradable polymer showed supple and elastic properties, with strain ability that reached + 31.5% and the yield point that occurred in tension (*stress*) of 0.75 MPa. The breaking point occurred in tension (*stress*) of 3.65 MPa. The thermal properties of biodegradable polymer showed that Jicama starch had a melting point of 105°C. SEM results conducted on biodegradability test showed the degradation in bioplastics that indicated the pores formation in bioplastics.

REFERENCES

[1] C. H.Tsou, M. C.Suen; W. H.Yao; J. T.Yeh; C.S.Wu, C. Y.Tsou, S. H.Chiu, J. C.Chen, R.Wang, S. M.Lin, W. S.Hung, M.Guzman, C. C.Hu, K. R. Lee, *Materials,* **2014,** *7*, 5617-563.2

[2] L. K.Mathew, *Int. J. Curr. Res. Aca. Rev,* **2015,** *3*(9), 15-19.

[3] D.Nawapat, W.Thawien, *Int. Food Res,* **2013,** *20*(3), 1313-1322.

[4] B.Imre, B.Pukánszky, *Eur. Polym. J*, **2013,** *49*, 1215–1233.

[5] N.Peelman, P.Ragaert, K.Ragaert, B.Meulenaer, F.Devlieghere, *J. Appl. Polym. Sci*, **2015,** *42305*, 1-15.

[6] J.Saharia, S. M.Sapuana, E. S.Zainudin, M. A.Malequed, *CarbohydrPolym,* **2013,** *92*, 1711– 1716.

[7] F.Xie, P.Luckman, J.Milne, L.McDonald, C.Young,C.Tu, T.Pasquale, R.Faveere, P.Halley, *J. Renew. Mater,* **2014,** *2,* 95-106.

[8] F.Pelissari, M.Andrade-Mahecha, P.Sobral, F.Menegalli, *Food Hydrocolloids,* **2013,** *30*, 681-690.

[9] V.Perez, M.Felix, A.Romero, A.Guerrero, *food bioprod. process*, **2016,** *9*, 100–108.

[10] M.Félix, J. E.Martín-Alfonso, A. Romero A. Guerrero, *Food Eng*, **2014,***125*, 7–16.

[11] M.Félix, A. Lucio-Villegas, A. Romero, A.Guerrero, *Ind. Crops Prod,* **2016,** *79,* 152–159.

[12] R.Lee, M. Pranata, Z. Ustunol, E. Almenar, *J. Food Eng*, **2013,** *118*, 132–140.

[13] K. Kaewtatip, V.Tanrattanakul, *Carbohydr. Polym,* **2008,** *73*, 647–655.

[14] A.Cano, E. Fortunati, M. Chafer, J.M. Kenny, A. Chiralt, C. Gonzalez-Martínez, *Food Hydro colloids,* **2015**, *48*, 84–93.

[15] M. Niazi, M. Zijlstra, A.Broekhuis, *Eur. Polym. J,* **2013,** *49*, 1861–1870.

[16] Z. Fei, S.Huang, J. Yin, F. Xu, Y.Zhang, *J. Polym. Environ*, **2015,** *23,* 383-391.

[17] E. M. Nakamura, L. Cordi, G. S. G. Almeida, N. Duran, L. H. I. Mei, *J. Mater. Process. Manuf. Sci,* **2005,** *162,* 236-241.

[18] G. M.Vinhas, S. M. Lima, L.A. Santos, M. A. G. A.Lima, Y. M. B. Almeida, *Braz. arch.Biol. technol,* **2007,** *50*, 361-370.

[19] E. Zinoviev, R. Rakhmatullin, I. Almazov, *J. Clin Exp Dermatol Res,* **2014,** *5(2)*, 1-3.

[20] M. Rohrbeck, C. Fischer, S.Wehner, J.Meier, W. Manz, *Wiley-VCH, Verlag GmbH, Germany*, **2014,** *26*, 42-47.

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